

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
20 June 2002 (20.06.2002)

PCT

(10) International Publication Number  
**WO 02/48546 A1**

REF ST AVAIL ABLE COPY

(51) International Patent Classification<sup>1</sup>: F03D 11/00, 1/06

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(21) International Application Number: PCT/DK01/00817

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(22) International Filing Date:  
11 December 2001 (11.12.2001)

Declaration under Rule 4.17:

— of inventorship (Rule 4.17(iv)) for US only

(25) Filing Language: English

Published:

— with international search report

(26) Publication Language: English

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(30) Priority Data:  
PA 2000 01868 13 December 2000 (13.12.2000) DK

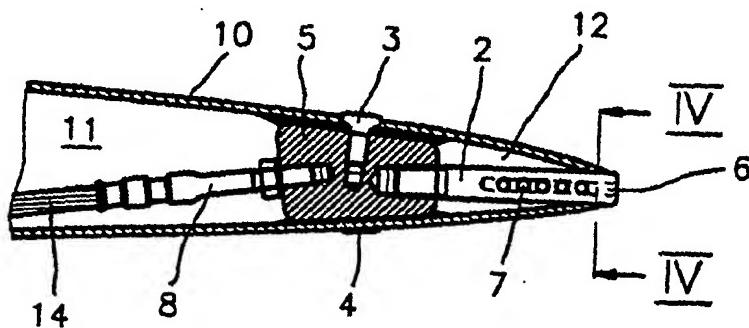
(71) Applicant (*for all designated States except US*): LM GLASFIBER A/S [DK/DK]; Rolles Møllevej 1, DK-6640 Lunderskov (DK).

(72) Inventor; and

(75) Inventor/Applicant (*for US only*): MØLLER LARSEN, Flemming [DK/DK]; Finksvej 5, Stubbum, DK-6070 Christiansfeld (DK).

(74) Agent: CHAS. HUDE A/S; 33, H.C. Andersens Boulevard, DK-1780 Copenhagen V (DK).

(54) Title: WIND TURBINE ROTOR BLADE WITH COMBINED LIGHTNING RECEPTOR AND DRAIN PASSAGE AND LIGHTNING RECEPTOR WITH DRAIN PASSAGE



(57) Abstract: The invention relates to a wind turbine rotor blade which in its tip (1) is provided with a lightning receptor (2) and a drain passage (6; 16; 26; 36; 46; 56) connecting the blade interior (11, 12) with the blade exterior, the drain passage (6; 16; 26; 36; 46; 56) and the lightning receptor (2) having a common interface. The invention further relates to a lightning receptor provided with a drain passage (6; 36; 46; 56).

WO 02/48546 A1

Title: Wind turbine rotor blade with combined lightning receptor and drain passage and lightning receptor with drain passage.

Technical Field

The invention relates to a wind turbine rotor blade, which in its tip is provided with  
5 a lightning receptor and a drain passage connecting the exterior of the blade with the  
interior thereof. Furthermore the invention relates to a lightning receptor.

Background Art

It is known to provide wind turbine rotor blades with lightning protection systems to  
protect them from strokes of lightning. As an example WO 96/07825 discloses a  
10 lightning protection arrangement, in which the blade tip is provided with a so-called  
lightning receptor of an electrically conducting material. This lightning receptor may  
capture a stroke of lightning and conduct the current through a lightning  
downconductor extending in the longitudinal direction of the blade and being earthed  
via the wind turbine hub. This system has proved to provide a particularly effective  
15 protection.

It is furthermore known to drill a drain bore in the tip of the wind turbine blade to  
drain off water, which has accumulated in the interior of the wind turbine blade in  
particular due to condensation.

Experience has shown that lightning may strike at such a drain bore, as this contains  
20 water. The lightning current heats the water and thus creates "steam explosions"  
resulting in such severe increases of the pressure that the blade is damaged. Lightning  
may strike in these drain bores even if the blade is provided with a lightning receptor.  
Due to the electric conductivity of the water in the drain bore, a spark may also fly  
between the lightning receptor and the drain bore. An effective drainage of the water

accumulated in the interior of the blade is, however, necessary, the water otherwise accumulating in the cracks and pores of the blade material and drawing lightning thereto. Finally it should be noted that the accumulation of water in the interior of the blade is undesirable in view of corrosion and as a large amount of water will act as a  
5 displaceable ballast and interfere with the rotation of the blades.

#### Description of the Invention

The object of the invention is to provide a new and improved lightning protection of wind turbine rotor blades.

10 According to the invention the object is obtained by providing the drain passage and the lightning receptor with a common interface. As a result the water accumulated in the interior of the blade may be effectively drained to the exterior of the blade at a very small risk of causing steam explosions, the lightning current being conducted away by the lightning receptor without intense heating of the water.

15 The drain passage may be a bore provided in the blade wall, the cross section of said bore exceeding that of the lightning receptor inserted through the bore. This solution is advantageous in that it can be used in connection with conventional lightning receptors.

According to the invention the drain passage may be provided in form of one or more  
20 recesses in the bore wall of a bore provided in the blade wall, a lightning receptor being inserted through the said bore. This is particularly simple and inexpensive solution.

According to the invention the drain passage may form part of the lightning receptor, whereby a particularly simple and reliable embodiment is obtained in that special  
25 embodiments of the bore in the blade wall thus being render superfluous.

- According to a preferred embodiment the lightning receptor is a cylindrical metal rod and the drain passage is a central longitudinal bore extending from the outermost end of the lightning receptor and communicating with transverse openings extending from the longitudinal bore to a surface area of the metal rod situated in the interior of the
- 5 blade in the mounted state of the lightning receptor. This is a particularly reliable embodiment in that it allows steam to escape easily, whereby the risk of explosive pressure increases is minimised. In a similar manner the drain passage is exclusively defined by the material of the lightning receptor, whereby the blade material is not subjected to an increase of pressure.
- 10 Optionally the drain passage may be provided in the form of one or more recesses in the surface of the lightning receptor, whereby a particularly simple and inexpensive embodiment is obtained.

#### Brief Description of the Drawings

The invention is explained in greater detail below by means of embodiments  
15 illustrated in the drawings, in which

Fig. 1 is a diagrammatic view of a portion of the blade tip of a wind turbine rotor blade a first embodiment of the invention,

Fig. 2 is a sectional view along the line II-II in Fig. 1,

Fig. 3 illustrates a second embodiment of the invention shown in the same manner as  
20 the embodiment shown in Fig. 2,

Fig. 4 is a sectional view along the line IV-IV in Fig. 2,

Fig. 5 is a sectional view along the line V-V in Fig. 3, and

Figs. 6-9 illustrates optional embodiments of the invention shown in the same manner as the embodiments shown in Figs. 4 and 5.

#### Best Modes for Carrying Out the Invention

Fig. 1 is diagrammatic view of a blade tip according to a first embodiment of the invention seen from one side of the blade. A lightning downconductor in form of a copper cable 14 is screwed onto an anchoring block 5 by means of a terminal means 8. By means of threaded connections three lightning receptors 2, 3, 4, eg of wolfram, are secured to the anchoring block 5 made of a conductive material, such as stainless steel, red brass or red bronze, said lightning receptors extending from the anchoring block 5 to the free end of the blade tip 1, the pressure side of the blade tip and the suction side of the blade tip, respectively. In the embodiment shown in Figs. 1, 2 and 4 a drain passage 6 is provided in the lightning receptor 2 extending from the anchoring block 5 to the free of the blade tip. The arrows 13 in Fig. 1 indicate how water from the interior of the blade may be drained to the exterior of the blade through the drain passage 6 in the lightning receptor 2.

The blade tip used to be filled with glue/resin/moulding material to a point beneath the anchoring block where a drain bore was provided in the blade wall. However, this method is problematic in that the glue/resin/moulding material shrinks on solidification and form cracks and pores in which water may accumulate.

Fig. 2 illustrates the first embodiment, in which the drain passage is formed of a longitudinal bore 6 in the lightning receptor 2 which has the shape of a circular wolfram rod. The longitudinal bore 6 opens into the distal end of the lightning receptor 2 on the outer face of the blade and communicates with the inner cavity 11, 12 of the blade through openings 7 in the lightning receptor 2. The areas of the interior 11, 12 of the blade on either side of the anchoring block 5 communicate with each other on both sides of the anchoring block 5 so as to allow water to flow from

the area 11 to the area 12 and out of the blade through the drain passage 6.

The blade tip shown in Fig. 3 is a second embodiment of the invention. In this embodiment the lightning receptor 2 is a solid circular rod inserted through a drain bore 16 having a slightly larger diameter than the diameter of the rod. As a result a 5 gap is created between the wall of the bore 16 and the surface of the receptor 2 through which water may escape to the exterior of the blade. This embodiment may be used in connection with conventional lightning receptors.

Figs. 5 - 9 are sectional views through the blade wall and the lightning receptor 2.

Figs. 4 and 5 are thus sectional views through the embodiments shown in Fig. 2 and 10 3, respectively.

Fig. 6 shows an embodiment in which the drain passage is formed as a groove 36 in the surface of the lightning receptor 2. In the embodiment shown in Fig. 7 the cross section of the drain passage 46 is formed as a section of the circular cross section of the lightning receptor 2.

15 Fig. 8 illustrates an embodiment in which the drain passage is a recess 26 in the wall of a circular bore through which the lightning receptor 2 has been inserted.

Fig. 9 shows an embodiment in which the drain passage is formed of several longitudinal grooves 56 in the surface of the lightning receptor 2.

The invention is not restricted to the above embodiments.

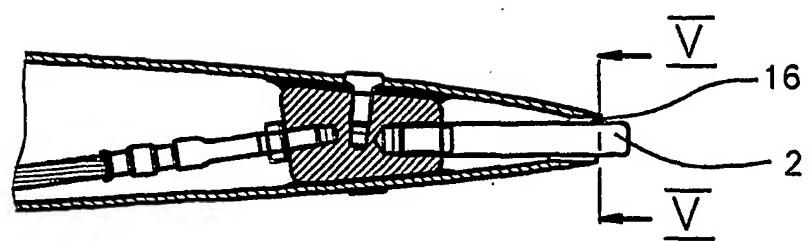
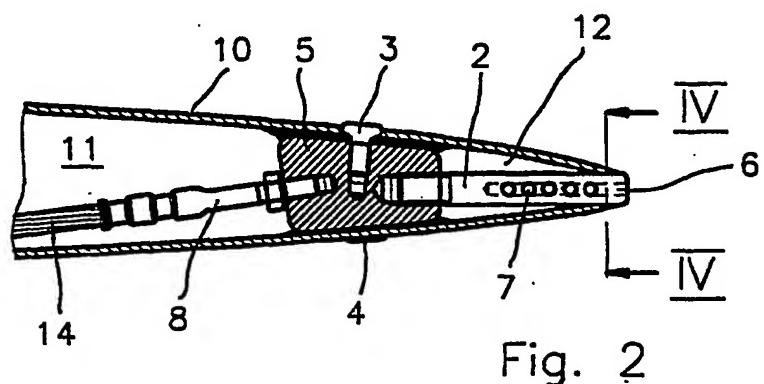
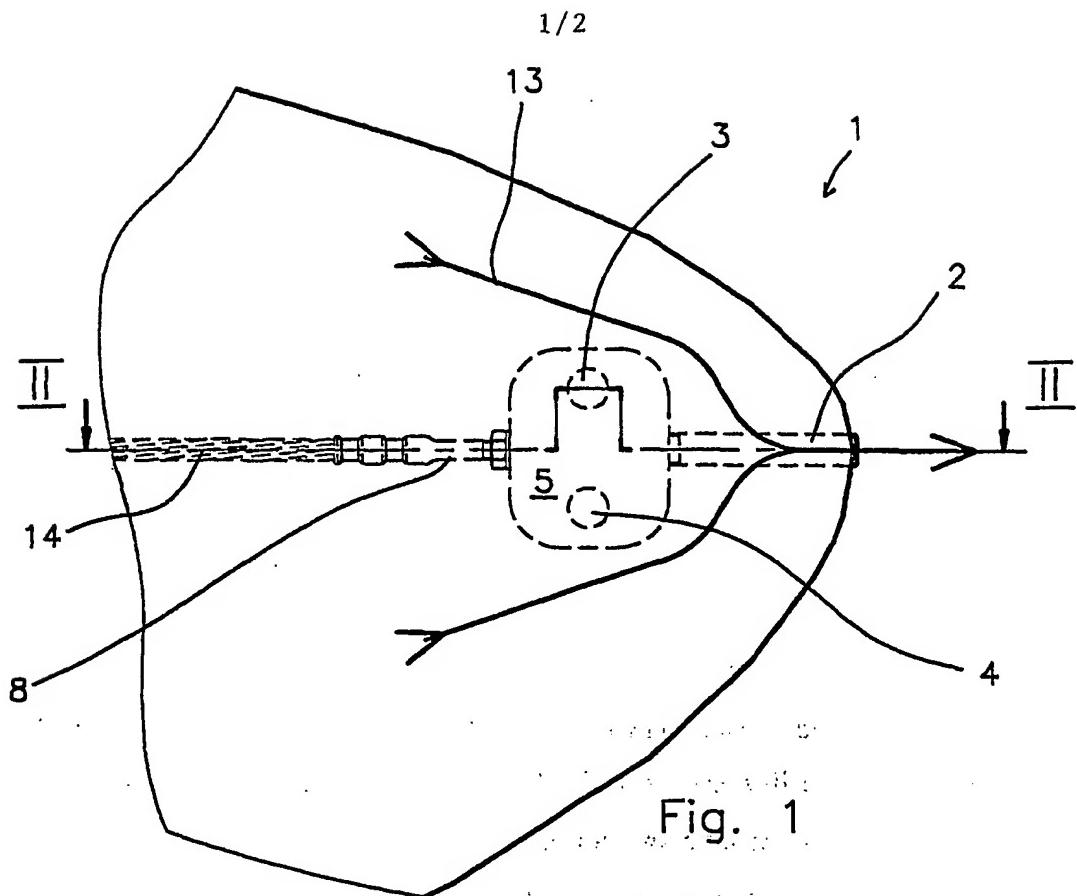
20 The shown lightning receptors 2 are formed as circular rods of a diameter of about 15 mm. The embodiment shown in Figs. 2 and 4 is provided with a drain passage of a diameter of about 6 mm. The lightning receptor and the drain passage may, however, have shapes and dimensions deviating from those shown.

The invention may be used both in connection with stall-controlled blades comprising a brake tip which is rotatable relative to the rest of the blade, and in connection with pitch-controlled blades.

Claims

1. Wind turbine rotor blade, which in its tip (1) is provided with a lightning receptor (2) and a drain passage (6; 16; 26; 36; 46; 56) connecting the blade interior (11, 12) with the blade exterior, characterised in that the drain passage (6; 16; 26; 36; 46; 56) and the lightning receptor (2) have a common interface.  
5
2. Wind turbine rotor blade according to claim 1, characterised in that the drain passage (6) is a bore (16) provided in the blade wall, the cross section of said bore exceeding that of the lightning receptor (2) inserted through the bore (16).
- 10 3. Wind turbine rotor blade according to claim 1, characterised in that the drain passage is formed of one or more recesses (26) in the bore wall of a bore provided in the blade wall, the lightning receptor (2) being inserted through the said bore.
- 15 4. Wind turbine rotor blade according to claim 1, characterised in that the drain passage (6; 36; 46; 56) is provided in the lightning receptor (2).
5. Lightning receptor (2) to be arranged in the tip of wind turbine rotor blade, characterised in that the lightning receptor (2) is provided with a drain passage (6; 36; 46; 56).
- 20 6. Lightning receptor (2) according to claim 5, characterised in that it is a cylindrical metal rod and that the drain passage is a central longitudinal bore (6) extending from the outermost end of the lightning receptor (2) and communicating with transverse openings (7) extending from the longitudinal bore (6) to a surface area of the metal rod, said surface being in the interior of the blade in the mounted state of the lightning receptor (2).

7. Lightning receptor (2) according to claim 5, characterised in that the drain passage is formed as one or more recesses (36; 46; 56) in the surface of the lightning receptor (2).



2 / 2

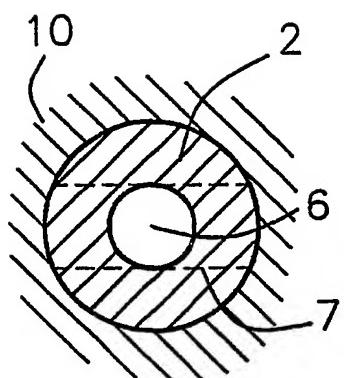


Fig. 4

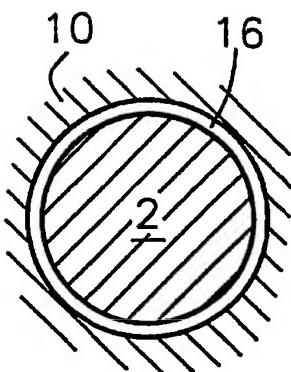


Fig. 5

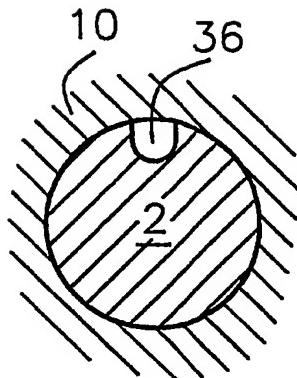


Fig. 6

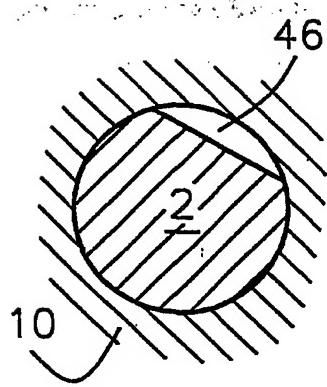


Fig. 7

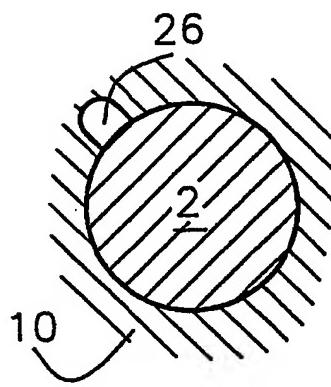


Fig. 8

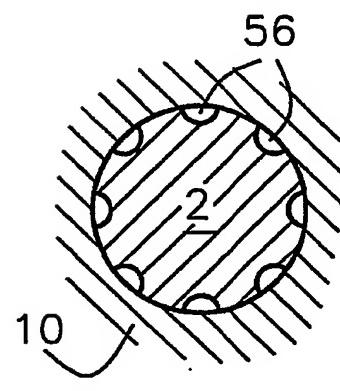


Fig. 9

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 01/00817

## A. CLASSIFICATION OF SUBJECT MATTER

**IPC7: F03D 11/00, F03D 1/06**  
 According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC7: F03D, H02G, H05F**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-INTENRAL, WPI DATA, PAJ**

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9607825 A1 (STIESDAL, H.), 14 March 1996 (14.03.96), figures 1-5, abstract --	1-7
A	WO 0014405 A1 (LM GLASFIBER), 16 March 2000 (16.03.00), figure 2, abstract --	1-7
P,A	WO 0079128 A1 (LM GLASFIBER), 28 December 2000 (28.12.00), figures 3,4, abstract --	1-7

 Further documents are listed in the continuation of Box C. See patent family annex.

\* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search  
**12 March 2002**

Date of mailing of the international search report  
**02.04.2002**

Name and mailing address of the International Searching Authority  
 European Patent Office P.B. 5918 Patentlaan 2  
 NL-2280 HV Rijswijk  
 Tel(+31-70)340-2040, Tx 31 651 epo nl.  
 Fax(+31-70)940-3018

Authorized officer

**Anna R-Salomonsson / MRO**  
 Telephone No.

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

28/01/02

International application No.

PCT/DK 01/00817

Patent document cited in search report	Publication date		Patent family member(s)	Publication date
WO 9607825 A1	14/03/96	AU	687875 B	05/03/98
		AU	3380295 A	27/03/96
		AU	7651894 A	03/04/95
		DE	29522152 U	02/03/00
		DE	69520220 D,T	21/06/01
		DK	9400343 U	13/10/95
		EP	0719318 A	03/07/96
		EP	0783629 A,B	16/07/97
		ES	2155527 T	16/05/01
		JP	9503006 T	25/03/97
		PT	783629 T	29/06/01
-----	-----	-----	-----	-----
WO 0014405 A1	16/03/00	AU	5504399 A	27/03/00
		CN	1317072 T	10/10/01
		DK	112798 A	10/03/00
		DK	173460 B	27/11/00
		EP	1112448 A	04/07/01
-----	-----	-----	-----	-----
WO 0079128 A1	28/12/00	AU	5390500 A	09/01/01
		DK	88199 A	22/12/00
		DK	173607 B	30/04/01
		NO	20016263 D	00/00/00
-----	-----	-----	-----	-----

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**